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Vulnerability of marine ecosystems to anthropogenic stressors

Jocelyn C. Nelson[1], Lucie C. Hannah[2], and Cathryn Clarke Murray[2]

[1] Pacific Biological Station, Fisheries and Oceans Canada, Nanaimo, BC, Canada [2] Institute of Ocean Sciences, Fisheries and Oceans Canada, Sidney, BC, Canada

Introduction

The vulnerability (or sensitivity) of ecosystem components to stressors or threats is a key component of any environmental assessment and is increasingly used in environmental impact assessment, cumulative effects assessment and cumulative impact mapping. However, not all studies define vulnerability in the same way and this can lead to variable and incompatible results.

> "An ecosystem's vulnerability to a threat determines the impact of a threat on a species or ecosystem" - Halpern et al. 2007

Vulnerability is often arranged as a matrix between ecosystems/species and stressors to give a relative score for each pair (vulnerability matrix). Scores are determined based on expert-elicitation and/or literature review (Teck et al. 2010). Both cumulative impact mapping and risk assessments define and use such vulnerability matrices.

Methods

In order to examine commonalities and differences among studies, we synthesized scores and relative ranking provided in published vulnerability and risk assessment studies. We examined definitions, criteria, methodology, and resulting scoring and relative rankings in ten studies of vulnerability. In these studies, vulnerability scores were calculated using a number of criteria – spatial scale, temporal scale, intensity, change, and recovery. The most commonly used terms to define vulnerability are shown in the word cloud in Figure 1.

Figure 1: A word cloud diagram displays the words most commonly used to describe the components of vulnerability. The larger the word font, the more often it appeared.

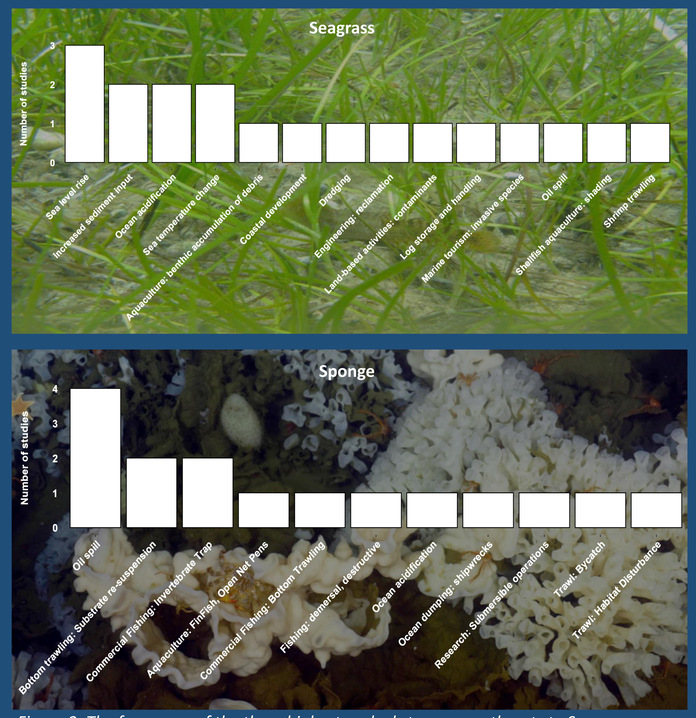


Figure 2: The frequency of the three highest ranked stressors as threats to Seagrasses (top) and Sponges (bottom). Seagrass and sponges were each evaluated in six of the ten studies.

Results

Vulnerability assessments have different scope, study area, components of interest, and stressors, making comparison difficult. However, there were some common components, and comparisons were able to be made with sponges (evaluated in six of ten studies) and seagrasses (six of ten). When the three highest impact threats for each study were compiled (Figure 2), sea level rise was the highest ranked threat for seagrasses (in the top three of 4 studies), whereas oil spill was the most often in the highest ranked threats for sponges (4 studies).

Nine of the ten studies included oil spill or inorganic pollution input as a stressor of interest, allowing a direct comparison of the vulnerability scores. The mean score for seagrass was 2.05 (± 0.3) and for sponges was 1.95 (± 0.3), each with a possible maximum of 3 (Figure 3). The spread in the data demonstrates that the criteria used and the study system will affect the resulting vulnerability scores. Care must be taken in transferring scores defined in one system (e.g., California current) to other systems of interest such as has been done for studies on British Columbia, Canada and Bering Strait, Alaska.

Moving forward

Vulnerability scores give a relative assessment of the impact of a stressor on an ecosystem or its components. This comparison of vulnerability definitions and rankings across different assessments will advance the understanding of cumulative effects assessments and the management of the risk of stressors.

In the next phase, we will produce a new vulnerability matrix for risk- and cumulative effects assessments in Canadian marine ecosystems. The updated vulnerability matrix will be used in cumulative impact mapping to inform marine spatial planning and ecosystems-based management.

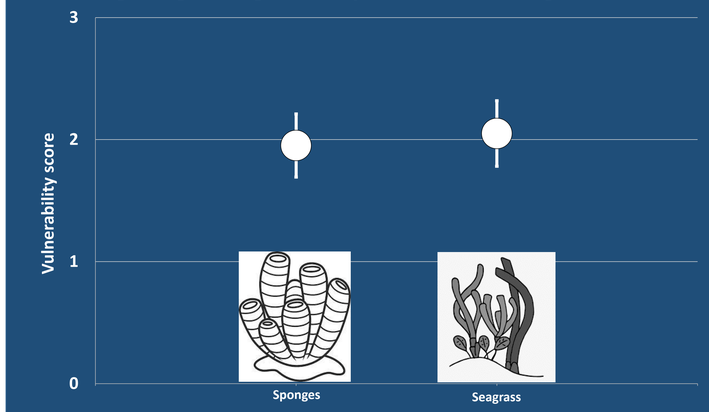


Figure 3: The mean vulnerability score for Sponges and Seagrasses to the oil spill or inorganic pollution stressor, error bars represent standard error. Scores were transformed across studies to a standard 1-3 scale for comparison.

References

Clarke Murray, C., S. Agbayani, H. M. Alidina & N. C. Ban (2015) Advancing marine cumulative effects mapping: An update in Canada's Pacific waters. Marine Policy, 58, 71-77.

DFO (2018) Ecological risk assessment and selection of risk-based indicators for the Hecate Strait and Queen Charlotte Sound Glass Sponge Reefs Marine Protected Area. CSAS Science Response Science Response 2018/040

Halpern, B. S., K. A. Selkoe, F. Micheli & C. V. Kappel (2007) Evaluating and ranking the vulnerability of global marine ecosystems to anthropogenic threats. Conservation Biology, 21, 1301-1315.

Hannah, L., C. St. Germain, S. Jeffery, S. Patton & M. O (2017) Application of a framework to assess vulnerability of biological components to ship-source oil spills in the marine environment in the Pacific Region. CSAS Research Document, 2017/057, 143.

MacDiarmid, A., A. McKenzie, J. Sturman, J. Beaumont, S. Mikaloff-Fletcher & J. Dunne (2012) Assessment of Anthropogenic Threats to New Zealand Marine Habitats. In New Zealand Aquatic Environment and Biodiversity Report, 255.

MPATT (2017) Interaction matrix

Murray, C. C., M. E. Mach & M. O. (2016) Pilot Ecosystem Risk Assessment to Assess Cumulative Risk to Species in the Pacific North Coast Integrated Management Area (PNCIMA). vii+59. Ottawa, ON.

O, M., R. Martone, L. Hannah, L. Greig, J. Boutillier & S. Patton. (2015) An Ecological Risk Assessment Framework (ERAF) for Ecosystem-based Oceans Management in the Pacific Region. vii+59. CSAS Research Document.

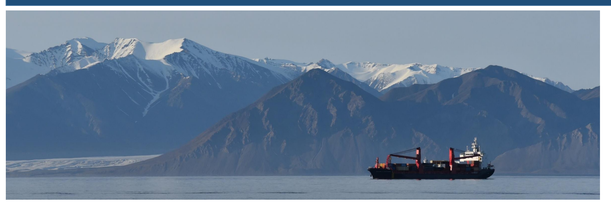
Rubidge, E., K. Thornborough & M. O. (2018) Ecological Risk Assessment for the Effects of Human Activities at the SGaan Kinghlas-Bowie Seamount Marine Protected Area. viii+98. CSAS Research Document.

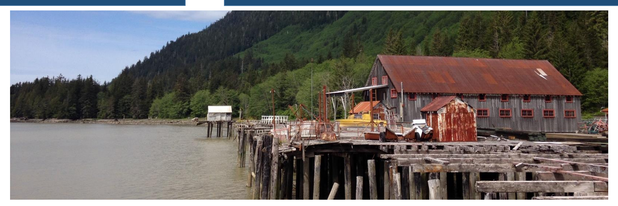
Teck, S. J., B. S. Halpern, C. V. Kappel, et al. (2010) Using expert judgment to estimate marine ecosystem vulnerability in the California Current. Ecological Applications, 20, 1402-1416.

Tamburello, N., Porter, M., Cueva-Bueno, P., et al. (2017) Linking Human uses to Ecosystem Components and Ecosystem Goods and Services in Canada's Northern Shelf Bioregion. Report prepared by ESSA Technologies Ltd. For Fisheries and Oceans Canada. 1013 pp + Appendices.

Thornborough, K., Rubidge, E., and O, M. (2018) Ecological Risk Assessment for the Effects of Human Activities at the Endeavour Hydrothermal Vents Marine Protected Area. DFO Can. Sci. Advis. Sec. Res. Doc. 2017/068.

Wilson, K., R. L. Pressey, A. Newton, M. Burgman, H. Possingham & C. Weston (2005) Measuring and incorporating vulnerability into conservation planning. Environ Manage, 35, 527-43.





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